INVESTIGATIONS CONCERNING THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

(Progress Report Number 3)

Respectfully Submitted,

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CONTENTS

	Page
INTRODUCTION	1
POTENTIAL VALUES OF BROOD RETARDATION	1
PROJECT II- A-1 - TREES FELLED ON LOGS AND TRIMMED AND UNTREATED (CONTROL) TREES	2
PROJECT II- A-4 - TREES FELLED ON GROUND AND TRIMMED	6
PROJECT IV- A-1 - POISONING INFESTED LODGEPOLE PINE TO KILL THE BROOD OF DENDROCTONUS MONTICOLAE	9
PROJECT V- A-2 - DETERMINATION OF STATUS OF INFESTATION BY BASAL EXAMINATION OF INFESTED TREES	17
PROJECT V- A-3 - VARIATION IN THE WORK DONE BY INSECTS IN ADVANCE GROUPS, MAIN BODY, AND REAR OF AN INFESTATION	20
SUMMARY	23

PROGRESS REPORT NUMBER 3

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INTRODUCTION

A serious epidemic of the mountain pine beetle has existed in western Montana for a number of years, where it has spread southward along the Continental Divide, killing as high as 60 per cent of the merchantable lodgepole and yellow pine timber over large areas. These losses and a threatened continuation of them made it advisable to initiate intensive studies of the insect with the object of securing more economical methods of artificial control, and to secure a better understanding of the factors of natural control. The epidemic having become well established on the East Fork of the Bitterroot River in 1925 and that area being conveniently located for investigative work, the investigations were initiated there that year. At first many projects were undertaken but the discovery that a vast amount of data was required for each study to secure an idea of representative conditions, made it necessary to greatly reduce the number of projects. Work during the 1927 and 1928 field seasons has been confined to lodgepole pine.

POTENTIAL VALUES OF BROOD RETARDATION

In two of the methods of control discussed in this report retardation of brood development has been considerable. The value of this retardation is uncertain, for though the development of the insect has been thrown out of balance with that of its host, the actual effect of this disturbance is difficult to measure.

The delayed emergence and subsequent attack may have the effect of materially reducing the number of working days, with a corresponding reduction in gallery length, fewer eggs, and consequent smaller brood. Furthermore, it is possible that the host would not be so susceptible to a delayed attack, and might even be more resistant to the development of the brood following attack. On the other hand, this possible reduction in brood numbers may be offset by a greater available food supply

within the attacked trees by decreasing the number of larvae which are competing for food within an area. Reduction in this competition may lower mortality within the broods.

How parasites and predators may be affected by this retarded development of the host can only be conjectured. Their host undoubtedly develops more slowly than normally, due to the lower temperature resulting in felled trees by contact with or proximity to the ground. If development of parasites and predators is closely synchronized with that of their hosts, the effectiveness of these beneficial insects may be considerably affected. The treatments used may so derange the development of the beneficial insects as to cause the beetle brood to equal or exceed that in untreated trees. Conversely the effectiveness of parasites and predators, or at least the more important ones, may be increased by the slower development of their host, resulting in a material reduction in the number of brood. To what extent these potential values have been realized is brought out in the discussions of the effect of the different treatments.

PROJECT II - A-1

TREES FELLED ON LOGS AND TRIMMED AND UNTREATED (CONTROL) TREES

Lodgepole pine trees infested with Dendroctonus monticolae were felled on logs and trimmed. In some cases trimming consisted of removing limbs to the height of infestation and then cutting off the top at that point, but often, owing to short crown or infested length, only severing the top of the tree from the bole was necessary. It was hoped by this treatment to secure an excess of moisture which might greatly retard brood development, the potential value of which has been discussed in the introduction. A further possible effect is the promotion of fungal and bacterial growth which might destroy the barkbeetle brood.

The general results of the treatment are shown in a condensed form in Table I and a comparison of brood mortality for the different treatments with that of control trees is shown in Figure 1 and Table IX. The brood was considerably reduced in number by the treatment but there still remained 7 insects to emerge for about 14 that attacked. The figure for emergence is an average secured from the extensive examination of 24 trees and consequently subject to the errors of such a method. It was also noticeable that parasites were fewer in the treated than in the check or control trees. This would indicate that retarding the development of the brood of the mountain pine beetle decreases the effectiveness of its parasites. Retardation of the brood development in various stages and a comparison of the amount with that of other treatments and of control trees is shown in Figure II.

The progress report of 1928 indicated results from this treatment in 1926 to be unfavorable but the small amount of available data was not considered representative of actual conditions. Trees treated by the same method in 1926 and 1927 and examined the following year, in both cases gave more encouraging results. As the amount of data for these two years was much greater than that for 1926, it is felt that the results can be considered much more indicative of actual conditions. The potential emergence was reduced to about 50 per cent of the number of insects attacking. In spite of this great reduction in the brood, the potential emergence is still considered too high to warrant recommending this method of treating as a control measure. In Table II may be seen a comparison of the data for this treatment and for control trees for 1926, 1927, and 1928. Table IX shows brood mortality data for 1928 for all treated and control trees.

Casual observations made while collecting the data from trees treated by this method indicated that solar heat is responsible for the death of a portion of the brood on the upper side of the tree. Brood and gallery length have been found to be in nearly the same proportion in an infested tree. In an analysis of eight of these treated trees it was found that gallery length on the upper side was approximately 28 per cent and brood only 10 per cent of the total of all four sides. Apparently solar heat was responsible for the reduction of the brood on the upper side of these trees to approximately one-third of the proportionate amount for that side.

With the brood reduced to approximately 50 per cent of the number of insects attacking, the possibility of turning the logs and still further reducing the brood will occur to many. Such a method is not feasible on the East Fork of the Bitterroot River due to the rarity and irregularity of occurrence of killing solar temperatures. In control work, waiting until such temperatures were secured would make it necessary to hold a large body of men for that event. As these high temperatures seldom occur before July 1, it would require turning all logs after such a temperature had occurred and the securing of a second killing temperature prior to emergence. As emergence usually begins during the last half of July the available time for turning all logs and obtaining a subsequent killing temperature, is very limited. Such a succession of events could not be expected. Under the most favorable conditions it would be doubtful if the method would be any more economical than present control measures, due primarily to the necessity of revisiting the control areas to turn the trees.

This method gave the most successful results of any so far tried, but still fails to completely destroy the brood and would be about as expensive to put into operation as the present peeling or burning methods. For the reasons discussed it is felt advisable to discontinue this project.

Table I

COMPARISON OF BROOD CONDITIONS IN TREES FELLED ON LOGS AND TRIMMED AND CONTROL TREES
LODGEPOLE PINE - 1926 - E. FORK - BITTERROOT

Square Foot Basis

Brood Status	TREATED TREES: Date	Total Number of Brood	Brood Retardation Compared with Control Trees	CONTROL TREES: Date	Total Number of Brood
80% larval	June 15	37	12 days	June 3	61
50% "	July 1	24	20 "	June 11	53
20% new adult	July 1	24	9 "	June 22	43

	TREATED: Average or Number	Range Determined by Standard Deviation*	CONTROL: Average or Number	Range Determined by Standard Deviation*
Number of trees examined	10	--	81	--
Number of square feet of bark surface examined	87	--	694	--
Attacks per square foot	6.8	2.7 - 10.9	9.3	3.9 - 14.9
Inches egg gallery per square foot	61	29 - 94	80	23-137
Possible emergence per square foot	7 #	2.0 - 21.2(1)	26	0 - 54
Possible emergence per square foot at 20% new adult stage	24	--	43	--
Per cent possible emergence is greater than attack at 20% new adult stage	76	--	131	--
Average diameter	11.1	--	10.7	--
Length of average egg gallery	9.0	--	8.4	--
Parasites per square foot	1.2	--	7.0	0.3 - 13.7
Average retardation of brood in treated trees for period from 80% larval to 20% new adult stage as compared with control trees --- 14 days.				

* Figures under standard deviation column indicate spread within which about 2/3 of data will fall.

\# Figure from extensive examination of 24 trees after emergence of brood and based on emergence holes. Subject to large possible error.

(1) For July 30 when brood was 11.6 per square foot.

Table II

COMPARISON OF BROOD CONDITIONS IN TREES FELLED ON LOGS AND TRIMMED AND CONTROL TREES
LODGEPOLE PINE - 1926-1927-1928 -- E. FORK -- BITTERROOT

Square Foot Basis

Date	Kind of Trees	Brood Retardation in Treated Trees Compared with Control Trees *	Inches of Gallery per Sq.Ft.	Attacks per Sq.Ft. (Two insects to each attack)	Brood at 80% New Adult Stage: Number per Sq.Ft.	Per cent Brood Number Greater than Number Attacking	Average D.B.H.	Number of TREES	Total Number of Single and Multiple Tree Examinations Made
1926	Treated	15 days #	60	12.6	29	134	--	10	18
	Control	--	60	13.0	28	114	11.2	22	27
1927	Treated	18 days	59	7.8	7	- 55	10.6	29	29
	Control	--	69	7.4	21	30	11.3	65	65
1928	Treated	14 days	61	6.8	7 (1)	- 52	11.1	10 (2)	10
	Control	--	80	9.3	34	84	10.7	81	81

*Average of (4) comparisons from 60% to 90% new adult stages.
#For 20 to 50% new adult period.
(1) Average figure for emergence secured from extensive examinations.
(2) Figures for final emergence are from 24 trees extensively examined.

PROJECT II - A-4

TREES FELLED ON GROUND AND TRIMMED

These trees were felled on the ground and trimmed, in the hope that contact with the ground and the removing of the branches would maintain a high moisture content detrimental to the infesting brood. Also, parasites and predators might be made more effective, bacterial or fungal growth possibly favored, and result in reduction of the brood, or such an excess of moisture might be secured as to drown the insects.

From a curve of the analyzed data in which average brood is plotted against time of examination, it is found that the potential emergence averaged 34.5 insects per square foot of bark surface on July 16, the date of the first record of emergence from control trees. In the treated trees the brood had been greatly retarded in development, as may be seen in Figure 2 and Table IX, and it is not believed emergence in any appreciable amount began until about August 1. By that time the brood was reduced to about 31 per square foot. On September 7 an extensive examination of 50 of these treated trees was made in the manner described in the preceding project. The average figure for emergence from the 50 trees so examined was found to be 12 per square foot. In Table III may be seen a comparison of data from this treatment and from control trees.

The average number of attacks per square foot was found to be about 7.4, making a total of 14.8 insects attacking per square foot of bark surface, when two insects are figured per attack. Comparing a possible emergence of 12 insects with attacks of 14.8 per square foot leaves an excess of insects attacking to those emerging of about 23 per cent. Figure 1 and Table IX show brood mortality for different treatments and for control trees.

Parasites were found to average about 0.5 per square foot, indicating that their effectiveness would be very slight. This figure is materially below that for control trees and suggests that the method of treatment had an effect upon the number of parasites. One side of the bole of the tree being in contact with the ground would make it very difficult for parasites and predators to reach the brood there. It is felt that this is partly responsible for the scarcity of parasites. A second factor that it is thought has reduced the number of parasites has been the retardation in the development of the host. Contact with the cold ground prevents the attaining

of normal developmental temperatures and consequent retardation in brood development. The apparent close synchronization of host and parasite would indicate that parasites are most numerous and efficient at the time the greatest quantity of host larvae are available. It is believed the parasite concentrates most of its activities on the last two larval instars of its host. Due to 23 days' developmental retardation the greater part of their host larvae in the treated trees are likely too small to be subject to parasitism at the time parasites are at their peak in numbers and efficiency. By the time the host larvae have reached their peak of parasite availability the parasites have likely greatly decreased in numbers and individual efficiency.

Retardation in development did not cause excessive mortality of the barkbeetle brood. Similar retardation was noted in the 1926 data but the small amount of data was believed insufficient to furnish data representative of actual conditions. It is felt that 1928 data are sufficient to be representative. Figure II and Table IX give an idea of brood retardation for the treated and control trees.

While the figure for emergence from the extensive examination subsequent to emergence is less than the number of insects attacking, it is felt that the number is still too high to warrant using this method of treatment as a control measure.

An unusual condition brought about by this experiment was caused by the trees lying on the ground. This consisted of a comparatively equal distribution of brood numbers for all the different stages of development. Normally one or two stages include a large per cent of the brood, while in this experiment all stages are well represented. The treatment had favored the survival of parent adults and a greater number survived in this experiment than in any other. The even temperature caused by the presence of snow over these logs for the greater part of the winter was doubtless largely responsible for the high rate of survival. These adults continued their activities in the spring with the result that eggs were being laid practically up to the time of emergence of the first insects from the tree. The proportion of other stages of development was also more equalized than for any of the treated or control trees. This equalization was due to two causes, a constant adding of new brood by the hatching of eggs laid by overwintering adults, and the uneven retardation in development of brood on the different sides of the felled tree. The brood on the bottom being in contact with the ground was retarded most, on the sides less, and on top the least in development, thus accounting for the wide range and comparatively equal distribution of brood stages. Figure II illustrates some of the brood retardation discussed.

No further work on this project is planned. The results hoped for from the retardation of brood development have not been realized and the emergence has been too great to justify continuation of the experiment as a possible control measure.

Table III

COMPARISON OF BROOD CONDITIONS IN TREES FELLED ON GROUND AND CONTROL TREES
LODGEPOLE PINE - 1928 - E. FORK - BITTERROOT

Square Foot Basis

Brood Status	TREATED TREES: Date	TREATED TREES: Total Number of Brood	TREATED TREES: Brood Retardation Compared with Control Trees	CONTROL TREES: Date	CONTROL TREES: Total Number of Brood
80% larval	June 21	44	18 days	June 3	61
50% "	July 1	39	20 "	" 11	53
20% "	" 17	34	26 "	" 21	44
20% new adults	" 3	38	12 "	" 21	44
50% " "	" 19	34	21 "	" 28	38
70% " "	" 28	32	25 "	July 3	35

	TREATED: Average or Number	TREATED: Range Determined by Standard Deviation*	CONTROL: Average or Number	CONTROL: Range Determined by Standard Deviation*
Number of trees examined	35	--	81	--
Number of square feet of bark surface examined	268	--	694	--
Attacks per square foot	7.4	2.8 - 12.0	9.3	3.9 - 14.9
Inches egg gallery per square foot	66	26 -106	80	23 - 137
Possible emergence per square foot	12#	3.2 - 56.2(1)	26	0 - 54
Possible emergence per square foot at 20% new adult stage	38	--	43	--
Per cent possible emergence is greater than attack at 20% new adult stage	157	--	131	--
Average diameter	11.6	--	10.7	--
Length of average egg gallery	9.0	--	8.4	--
Parasites per square foot	0.5	--	7.0	0.3 - 13.7

Average retardation of brood in treated trees for period from 50 to 70% new adult stage as compared with control trees -- 23 days.

* Figures under standard deviation column indicate spread within which about two-thirds of data will fall.
\# Figure from extensive examination of 50 trees after emergence of brood and based on emergence holes.
(1) Based on average number of brood on August 8.

PROJECT IV - A-1

POISONING INFESTED LODGEPOLE PINE TO KILL THE

BROOD OF DENDROCTONUS MONTICOLAE

Injecting poison into a tree seemed to offer possibilities of developing a cheap and effective method of control of the mountain pine beetle. Experiments were begun in a small way in 1926, using arsenite and arsenate of sodium. A downward slanting hole one-half or three-fourths of an inch in diameter was bored in the tree nearly through the sapwood on the far side to make available two areas of conducting tissue. From one to four ounces of crystalline poison were placed in the upper end of the hole, then flushed down and dissolved by pouring in water. Beetle development was apparently unaffected by the treatment.

During 1927 a more thorough method of injecting poison was developed. The equipment used consisted of cans of either one or two-quarts' capacity, open at the top, and having a copper tube one-quarter inch in diameter and two inches long soldered into the bottom of the can. A similar piece of tubing was inserted in the cork, the latter then being tightly fitted into a one-inch downward-slanting hole bored in the tree about three feet above the ground. Connection between the can and the hole in the tree was then made by a short piece of rubber tubing, the can then being hung on a nail driven in the tree 18 to 30 inches above the hole.

When the apparatus had been set up, a solution of one or two ounces of poison dissolved in a quart of water was poured in the can. In most cases the solution was absorbed rapidly, usually 50 per cent of the quart cans being emptied in 24 hours, with the two-quart cans taking somewhat longer. Practically all solution was absorbed in 48 hours. Little uniformity was noted in rate of absorption. In some cases a tree eight inches in diameter absorbed the contents of a two-quart can in half the time it took a 12-inch tree to absorb the contents of a one-quart can.

The general methods used in connection with the poisoning experiment since its inception in 1926 are outlined in Table IV. The sites were roughly classified into six: north, south, east, and west slopes, low flat, and high flat. In 1926 the low flat type was the only one represented in the experiment. In 1927 only the east slope and the high flat sites were the only ones not represented. In 1928, east, west, and south slopes were omitted.

All the poisoning was done at one time in 1926. In 1927 20 trees per week were poisoned for six successive weeks to determine the effect time of treating had on brood development. As no difference was observed by varying the date of treatment, the treating periods were not regularly spaced and reduced to three, in 1928. The wide range of diameter limits for poisoned trees in 1926 and 1927 was reduced to practically five inches in 1928 to lessen the variability in insect work known to occur with differences in diameter. Only a lack of available trees prevented reducing this diameter limit still further.

During 1926 and 1927 two poisons were used in varying doses. The number of poisons was increased in 1928, while those used the two previous years were again tried, using much heavier doses. In 1926 the foliage of the poisoned trees seemed to fade much more quickly than for adjacent untreated trees. The same observation was made in 1927, with the group poisoned the first week in September showing the most rapid change. In this group 35 per cent of the trees had started to fade in four days, and 100 per cent in seven days. Under normal conditions few lodgepole pine infested with Dendroctonus monticolae start to fade prior to May or June of the year following the attack.

The groups selected in 1927 were located so they might give some indication of conditions in different parts of an infestation. While it was thought possible some direct killing of infesting brood might occur from the insects eating poisoned tree tissue, it was supposed the greatest control would be secured indirectly by changing the insect's environment. Abnormal moisture conditions might develop and result in one of three things: (1) drowning the brood; (2) rendering its food toxic by promoting fungal or bacterial action; or (3) delaying normal development, thus exposing the brood to parasites and predators for an abnormally long time, with consequent marked reduction in the final number of barkbeetles emerging. Another result thought possible was a reduction in the length of the average egg gallery and the number of eggs laid. It was hoped the poison might stop egg gallery extension by killing the adult insects, or at least reduce their activity by rendering their food less palatable.

Examinations made in 1928 fail to maintain hopes of a complete control. Potential emergence remained higher than attack, the average number of attacks being 10.4, and potential emergence 24. Counting two insects per attack made 20.8 insects attacking to 24 emerging, a difference of 3.2, which is about 15 per cent greater than the number attacking. While less than the averages obtained for the control trees, which showed 26.5 insects potentially emerging to 18.6 attacking, making an excess of emergence over attack of about 42 per cent, the difference

between treated and control trees is too small and the standard deviations in both cases too great to make the figures of definite significance. Even if slight reduction in emergence was secured the hoped-for increase in parasitism did not materialize, and parasite concentration was about equal in control and poisoned trees. Table V gives a comparison of poisoned and control trees. Figure 1 and Table IX gives a comparison of brood mortality for treated and control trees.

Table IV

GENERAL DATA OF POISONING EXPERIMENT IN LODGEPOLE PINE
E. FORK -- BITTERROOT

Date	Number of Sites Represented*	Number of Periods when Trees were Poisoned	Time of Poisoning	Method Employed in Poisoning Trees	Diameter Range of Poisoned Trees in Inches, D.B.H.	Number of Trees Poisoned	Poisons Used
1926	1	1	Aug. 24-31	Dry poison flushed into hole bored in tree and dissolved by water.	8-13	12	Sodium arsenate " arsenite
1927	4	6	Weekly from 1st week in August.	Injection by connecting solution-filled cans with hole bored in tree.	6-17	120	Sodium arsenate " arsenite
1928	3	3	2nd and 4th week in August. 2nd week in September.	Injection by connecting solution-filled cans with hole bored in tree.	10-14	105	Sodium arsenate Hellebore Black Leaf "40" Potassium cyanide Sodium hydroxide Carbon disulphide

* Maximum number of sites possible is six.

Table V

COMPARISON OF BROOD CONDITIONS IN POISONED AND CONTROL TREES
LODGEPOLE PINE - 1928 -- E. FORK - BITTERROOT

Square Foot Basis

	TREATED TREES			CONTROL TREES	
Brood Status	Date	Total Number of Brood	Brood Retardation Compared with Control Trees	Date	Total Number of Brood
80% Larval	June 2	49	+ 1 days	June 3	61
50% "	" 8	43	+ 3 "	" 11	53
20% "	" 20	35	+ 1 "	" 21	44
20% New Adults	" 16	36	+ 5 "	" 21	44
50% " "	" 25	31	+ 3 "	" 28	38
80% " "	July 6	27	- 2 "	July 4	34

	TREATED		CONTROL	
	Average or Number	Range Determined by Standard Deviation*	Average or Number	Range Determined by Standard Deviation*
Number of trees examined	140		81	
" " square feet of bark surface examined	797		694	
Attacks per square foot	10.1	4.7 - 15.5	9.3	3.9 - 14.9
Inches egg gallery per square foot	83	39 - 127	80	23 - 137
Possible emergence per square foot	24	3 - 45	26	0 - 54
" " " " " at 20% new adult stage	36		43	
Per cent possible emergence is greater than attack, July 1 basis	27		93	
" " " " " " " " at 20% new adult stage	64		131	
Average diameter	11.0	8.7 - 13.3	10.7	
Length of average egg gallery	8.2		8.4	
Parasites per square foot	6.8	0 - 14.0	7.0	0.3 - 13.7
Average retardation of brood in treated trees for period from 50 to 80% new adult stage as compared with control trees --+ 0.5 days				

* Figures under standard deviation column indicate spread within which about two-thirds of data will fall.

It is believed Coloides brunneus is the insect composing the greatest part of the figures on parasitism. An idea of the effectiveness of parasites may be gained from the following tabulation.

Table VI

PARASITES OF D. MONTICOLAE IN INFESTED LODGEPOLE PINE
E. FORK -- BITTERROOT - 1928

Treatment of Trees	No. of Trees	Av. No. of Parasites per Sq. Ft. of Bark Surface	Range Determined by Standard Deviation	Estimated Av. Barkbeetle Emergence per Sq. Ft.	Per Cent Parasites are of Estimated Emergence *
Poisoned	121	6.8	0 - 14.0	24	30
Control	47	7.3	0.8 - 13.8	26	27

* This figure is derived by dividing the number of parasites by the estimated number of beetles emerging.

It is seen from the average figures presented in Table VI that parasitism in poisoned trees varies little, if any, from that in control trees, so it is a reasonably safe assumption that the treatment had no effect on the concentration of parasites. During the period when barkbeetle brood is being constantly reduced by mortality, parasites are increasing, although slowly, while the number of barkbeetle larvae decreases. This change in the relationship of the two factors is shown in Table VII, the materials for which are averages taken from curves.

Table VII

COMPARISON OF PARASITE AND BARKBEETLE STATUS IN LODGEPOLE PINE TREATED BY POISONING - 1928

Date	Average Barkbeetle Brood per Sq. Ft.	Average Number Parasites per Sq. Ft.	Per Cent Parasites are of Barkbeetle Brood
May 20	69.0	--	--
May 30	52.0	--	--
June 10	41.0	5.7	14
June 20	34.0	6.3	19
June 30	29.0	6.7	23
July 10	25.0	7.0	28
July 15*	24.0	7.1	30
July 20	23.5 #	7.2	31
July 30	23.0 #	7.3	32

* Emergence commenced about July 16.
# Based on brood present supplemented by estimate of emergence. Definite count not practicable.

The preceding table shows that in the decrease in brood and increase in number of parasites the percentage relation of parasites to brood is magnified. The figures given in Table VII do not show the extremes and tendencies due to deviations from these averages.

A comparison of the poisoned tree groups, according to various sites and time of treating, showed no differences which could not be assigned to the normally wide variations of the data. A comparison between the sodium arsenite and the sodium arsenate poisoned trees for the effect of these two chemicals showed no difference. A comparison of treated and control trees for brood development indicated a possible slight acceleration in poisoned trees. Figure II and Table IX show the development of brood for treated and control trees.

From the evidence so far presented, it is apparent that poisoning D. monticolae-infested lodgepole pine, as practiced in 1927, has little or no effect in controlling the infesting brood. The unfavorable results were anticipated before examinations were completed in 1928. Assigning definite reasons for the failure of the experiment will not be attempted. Some trees showed complete control of the brood, but as the same condition was duplicated in the control trees, no credit can be given the method for the insect mortality that occurred. It is possible the dose injected in the tree is too small. To secure some idea of the distribution of poison, sections from two trees were sent to the Bureau of Chemistry and Soils at Washington for arsenical analysis. Their report follows.

Lodgepole injected with sodium arsenate

			As_2O_3 Parts per million	
		No.		
Tree No. 1		1	5 -	- North sapwood
Injected on		2	16 -	- North heartwood
north side	30 ft.	3	negative	- Center
one ounce		4	trace	- South heartwood
		5	20	- South sapwood
		6	15 -	- North sapwood
		7	negative	- North heartwood
	1 ft.	8	13	- Center
		9	negative	- South heartwood
		10	trace	- South sapwood
Tree No. 7		11	147 -	- South sapwood
Injected on		12	15 -	- South heartwood
south side	30 ft.	13	31 -	- Center
two ounces		14	29 -	- North heartwood
		15	13 -	- North sapwood
		16	17 -	- South sapwood
		17	17 -	- South heartwood
	1 ft.	18	30 -	- Center
		19	72 -	- North heartwood
		20	22 -	- North sapwood

The two trees tested were both 5 inches in diameter breast high and of approximately the same height. The much larger amount of poison found in Tree No. 7 may have been due to the larger dose it received. Still larger doses may distribute sufficient poison through the tree to kill the cambium-feeding brood.

Believing the quantity used previously may have been too small, in 1928 much heavier doses were administered. The former maximum of two ounces of poison per tree was raised to 5 ounces in 1928, and a minimum of 4 ounces established. Other chemicals at varying strengths were also tried, consisting of carbon disulphide, potassium cyanide, sodium hydroxide, hellebore, and black leaf "40". This was dissolved in water and injected in the trees, using the same equipment as that used in 1927.

Some slight changes were made in the method of injecting materials in 1928. Holes were bored entirely through the tree and the one opposite the can plugged with a cork. This favored faster boring of the trees and a greater surface of conducting tissue. The holes were bored with less downward slant, to facilitate the making of a tight joint where the cork is inserted in the tree.

Although failure has marked all efforts to control barkbeetle brood by injecting poison in an infested tree, no intention of abandoning the project is entertained. If an insect-destroying medium can be found it is believed the injection method will prove more economical than any so far devised. Furthermore, the field of possibilities for the control of barkbeetles by injecting chemicals in the infested tree has hardly been touched up to the present time.

An advantage possessed by the injection method is the comparatively small amount of equipment required. It can also be used repeatedly. If the rate of absorption of arsenic represents the average, the cans can be removed from the treated trees no later than the third day and used again immediately.

A phase of the injection method that requires study is the distribution of poison in the tree. The present method, in which a hole is bored entirely through a tree so two areas of conducting tissue are available, may be found inadequate. Two or three such holes per tree may be necessary. That the distribution by the present method is unequal is shown by the Bureau of Chemistry and Soils report on page 15. It is planned to study the distribution of materials injected in a tree, using stains and the same method as that used with poisons.

Continuation of this project in the same manner and with the same materials depends upon the results of examinations to be made during the season of 1929. Other chemicals and more promising methods may favor continuation of the project along somewhat different lines if negative results are obtained in 1929. The use of stains to study the distribution of injected materials in a tree is planned for the field season of 1929.

PROJECT V - A-2

DETERMINATION OF STATUS OF INFESTATION BY BASAL EXAMINATION OF INFESTED TREES

Data from a large number of trees are necessary to secure the status of an infestation within a stand. The intensive method of examining trees infested with barkbeetle brood, as practiced on the Bitterroot project, requires a great deal of time, personnel, and money. These disadvantages made it advisable to seek a less intensive and equally accurate method.

Examination of brood and insect work under one-eighth of a square foot of bark surface on each of the four sides of the tree at five feet above the ground, was decided upon. This project was begun in 1927. An analysis of that year's data encouraged further study. In 1928 similar examinations were made on all treated and control trees prior to the intensive examination. The two sets of data gave an opportunity to compare both methods, using data from the same trees, thus furnishing an accurate index of the value of the extensive method when compared with the intensive one.

To determine the reliability of the data secured it is necessary that the standard deviation be secured for each method. Results of the analysis of the data for the tree and the basal examinations are shown in Table VIII. The unit employed in analysis of the material for the intensive examination was the total of the four one-quarter square-foot under-bark examinations made at each ten-foot interval. The unit for the basal examinations was the total of the four one-eighth square-foot under-bark examinations made at a height of five feet above the ground.

It is noticeable in comparing basal examination figures with those for ten-foot intervals, that basal examinations show an excess of gallery length. This is to be expected. The greatest concentration of insect work is found in the lower part of the tree. An

average of samples from all parts of a tree will naturally be lower than the average for a basal examination. In this case the excess of gallery length for the basal sections over that of the entire tree is about 35 per cent, and means the basal examination is too high for an average of tree conditions by about that amount. These figures apply only to gallery length, but from observations of the other factors it is believed gallery length will also give a fair indication of the variations for attacks and brood.

In Table VIII both poison and control trees are compared for the two methods of examination. If the figures for the two sets of comparisons are indicative of average conditions, there is no exact uniformity in variation. For control trees the coefficient of variation is greatest for the basal examinations and amounts to 10 per cent more than the variation for the ten-foot interval examinations. For poisoned trees conditions were reversed, basal examinations showing less coefficient of variation than the ten-foot interval figures by 12 per cent. It is believed the basal examination method bears promise of furnishing as accurate data for comparative purposes as the present more intensive method. With a correction factor it may even furnish a fair idea of tree contents. It is recommended that this method be given more thorough study with the idea of adopting it as the method to be used for comparative purposes.

Table VIII

COMPARISON OF ENTIRE TREE AND BASAL METHOD OF EXAMINATIONS
TO DETERMINE INFESTATION STATUS
E. FORK - BITTERROOT - 1928

For D. monticolae in Poisoned and Control Trees

CONTROL TREES

Averages and Deviations of Gallery Length per Square Foot

Method of Examining	Average (1)	Standard Deviation(2)	Range Determined by Standard Deviation	Coefficient of Variation(3)	No. of Samples in Data
Ten-foot intervals for entire tree	78	26	50-106	36%	694
Basal examination	105	48	57-153	46%	75
POISONED TREES					
Ten-foot intervals for entire tree	83	44	39-127	53%	801
Basal examination	108	44	64-152	41%	103

(1) Arithmetic average.
(2) The standard deviation indicates spread within which about two-thirds of data will fall.
(3) The coefficient of variation is the standard deviation expressed as a percentage of the arithmetic average.

Table IX

BROOD MORTALITY FOR TREATED AND CONTROL TREES -- E. FORK - BITTERROOT - 1928
LODGEPOLE PINE INFESTED WITH D. MONTICOLAE

Date of Examination	Poisoned Trees: Brood per Sq. Ft. of Bark Surface	Poisoned Trees: Per Cent of Brood on 5/10 (1)	Control Trees: Brood per Sq. Ft. of Bark Surface	Control Trees: Per Cent of Brood on 5/10 (1)	Felled on Ground and Trimmed*: Brood per Sq. Ft. of Bark Surface	Felled on Ground and Trimmed*: Per Cent of Brood on 5/15 (1)	Felled on Logs and Trimmed #: Brood per Sq. Ft. of Bark Surface	Felled on Logs and Trimmed #: Per Cent of Brood on 6/5 (1)
May 10	126	100	105	100	--	--	--	--
May 11	114	91	100	95	--	--	--	--
May 12	106	84	97	92	--	--	--	--
May 14	94	75	92	88	--	--	--	--
May 15	89	71	90	86	92	100	--	--
May 20	72	57	80	76	75	82	--	--
May 25	60	48	72	69	68	74	--	--
May 30	52	41	66	63	61	66	--	--
June 5	45	36	59	56	55	60	51	100
June 15	36	29	49	47	47	51	37	73
June 25	31	25	40	38	42	46	28	55
July 5	27	21	33	31	38	41	22	43
July 15	25	20	27(2)	26	35	38	17	33
July 20	--	--	--	--	33	36	15	29
July 25	--	--	--	--	32	35	13	24
July 30	--	--	--	--	32	35	12 (2)	24
Aug. 5	--	--	--	--	31 (2)	34	11	22
Aug. 10	--	--	--	--	30	33	11	22

* Average retardation in brood development 23 days.
\# " " " " " 14 "

(1) The initial date of examination is the basis of comparison and is considered as 100 per cent.
(2) These duplicate figures under treated and control trees are comparable due to the retardation in brood development.

PROJECT V - A-3

VARIATION IN THE WORK DONE BY INSECTS IN ADVANCE GROUPS, MAIN BODY, AND REAR OF AN INFESTATION

It was noticeable in making examinations of untreated trees during the season of 1927 that brood numbers per square foot in the more advanced groups of infested trees exceeded those in the main body of the infestation and these in turn exceeded the brood numbers in the rear of the infestation. The amount of data secured in 1927 was meager, and to determine more conclusively if the differences noted were definite a much larger amount of data was collected in 1928. The results of it are shown in Table X.

Differences in insect status were expected for the different parts of an infestation. Where the insects are invading a new area they have the maximum amount and the greatest choice of food. They are also comparatively few in numbers, are separated considerably from the main body of the infestation, and should not be as much subject to attack by agencies of natural control. Under such favorable conditions they can be expected to develop the largest brood of any part of the infestation. The factors of natural control can usually be expected to be concentrated most heavily in the area where insects are in the greatest abundance.

The average conditions we can expect to find may then be considered in three different classifications: lowest, medium, and highest, as shown in the outline following.

Theoretical Conditions for the Three Main Parts of a Dendroctonus Monticolae Infestation

	Brood Numbers	Attacks per Sq.Ft.	Inches Gallery per Sq. Ft.	Parasites per Sq. Ft. *
Advance Group	Highest	Lowest	Lowest	Lowest
Main Body	Medium	Medium	Medium	Medium
Rear Groups	Lowest	Highest	Highest	Highest

* Parasites are believed to advance to newly attacked trees from the trees attacked two years previous. [redacted]. That would make the parasites most highly concentrated somewhat to the rear of the main body in an advancing infestation.

The order as actually found from the data was as follows.

Actual Conditions for the Three Main Parts of a
Dendroctonus Monticolae Infestation
as Determined from 1928 Data

Part of Infestation	Brood Numbers	Attacks per Sq. Ft.	Inches Gallery per Sq. Ft.	Parasites per Sq. Ft.
Advance Groups	Highest	Medium	Medium	Lowest
Main Body	Medium	Lowest	Lowest	Highest
Rear Groups	Lowest	Highest	Highest	Medium

From a comparison of the two outlines it is seen that for the advance groups only brood and parasite conditions occurred as expected. In the main body brood was the only factor occurring as expected. In the rear groups parasites were the only factor not found as expected. In no case was the order expected completely reversed, that is, the highest order did not replace the lowest in any case. In six of the twelve cases conditions were found according to expectations, in six others, conditions were only in the class next in order, which would be well in the range of normal variation of the data. From the data so far collected, there is evidence of a fairly definite difference in the status of insect work in advance, main body, and rear of an infestation. Such knowledge has a practical value in that it indicates what part of an infestation it would be most profitable to control when insufficient funds are available to treat the entire infested area.

It is not planned to give this project any further study at present, as it is felt that the data secured were sufficient to indicate conditions.

Table X

COMPARISON OF UNTREATED LODGEPOLE PINE INFESTED WITH D. MONTICOLAE IN ADVANCE GROUPS, MAIN BODY, AND REAR OF THE INFESTATION
E. FORK -- BITTERROOT - 1928

Figures Given are on Square Foot of Bark Surface Basis

	Av. No. of Brood (1)	Standard Deviation (2)	Range as Determined by Standard Deviation	Average No. of Attacks (1)	Standard Deviation (2)	Range as Determined by Standard Deviation	Av. Inches of Gallery (1)	Standard Deviation (2)	Range as Determined by Standard Deviation	No. of Parasites	% Parasites are of Brood (3)
Advance Groups(4)	67	44	23-111	11.5	7.8	3.7 - 19.3	85	53	32 - 138	2.5	4.1
Main Body	27	27	0-54	9.4	5.5	3.9 - 14.9	78	28	50 - 106	7.3	14.4
Rear Groups	11	11	0-22	12.1	6.9	5.2 - 19.0	88	46.5	41.5 -134.5	5.1	31.3
Big Hole (Advance Group)	28	43	0-71	11.4	6.9	4.5 - 18.3	83	49	34 - 132	3.2	11.4

	Advance Groups(4)	Main Body	Rear Groups	Big Hole (Advance Group)
Average date for data given	June 21	July 13	July 6	July 22
Average diameter	10.4	10.6	10.5	11.7
Number of trees examined	31	81	23	66
Number of observations making up data	207	694	161	218

(1) Arithmetic average.
(2) The standard deviation indicates the spread within which about two-thirds of data will fall.
(3) For example, if the brood should number 24 and the parasites 6 per unit of area, the per cent parasites are of brood would be $6 \div 24 = 25\%$.
(4) Exclusive of data from Big Hole Basin.

SUMMARY

This summary is a brief statement of the more significant results obtained from the studies discussed in this report. Complete destruction of the brood was not obtained in any of the control methods. Emergence in the trees felled on logs and trimmed was reduced to about half the number of insects attacking. Trees treated by felling on the ground showed an emergence somewhat less than the number of insects attacking.

Brood retardation was considerable in both of the treatments just discussed but its value as a control measure seems small. No such retardation was noted in the trees poisoned to kill the infesting brood.

The attempt to either directly or indirectly kill the brood by injecting poison into the infested trees has met with no success up to the present time. However, the poison did have the effect of accelerating the fading of the foliage and consequent death of the tree.

The basal examination of a small area on each side of standing infested trees, near the base, and drawing conclusions from the data obtained, give considerable promise of being a shorter, adequate method than our present intensive method of examination for the determination of the status of an insect infestation.

The differences observed in the status of the mountain pine beetle in 1927 in the advance groups, main body, and rear groups of the infestation on the East Fork were again noted in 1928 when much more representative data were secured. These differences emphasize the necessity of examining trees in all parts of an infestation to determine representative conditions.

In addition to the general projects studied on the Bitterroot, two separate projects were assigned to individuals and carried on during the 1928 field season. Deleon began the study of the role of parasites and predators in a mountain pine beetle infestation and has already submitted his report on the findings. Rust studied the effectiveness of the peeling method of control upon the survival of the brood of Dendroctonus monticolae, on which a report has already been submitted.

The study of parasites and predators begun by Deleon is to be continued in 1929 on the Bitterroot and in the Big Hole Basin. The study begun by Rust will be continued in the white pine stands.

Figure I

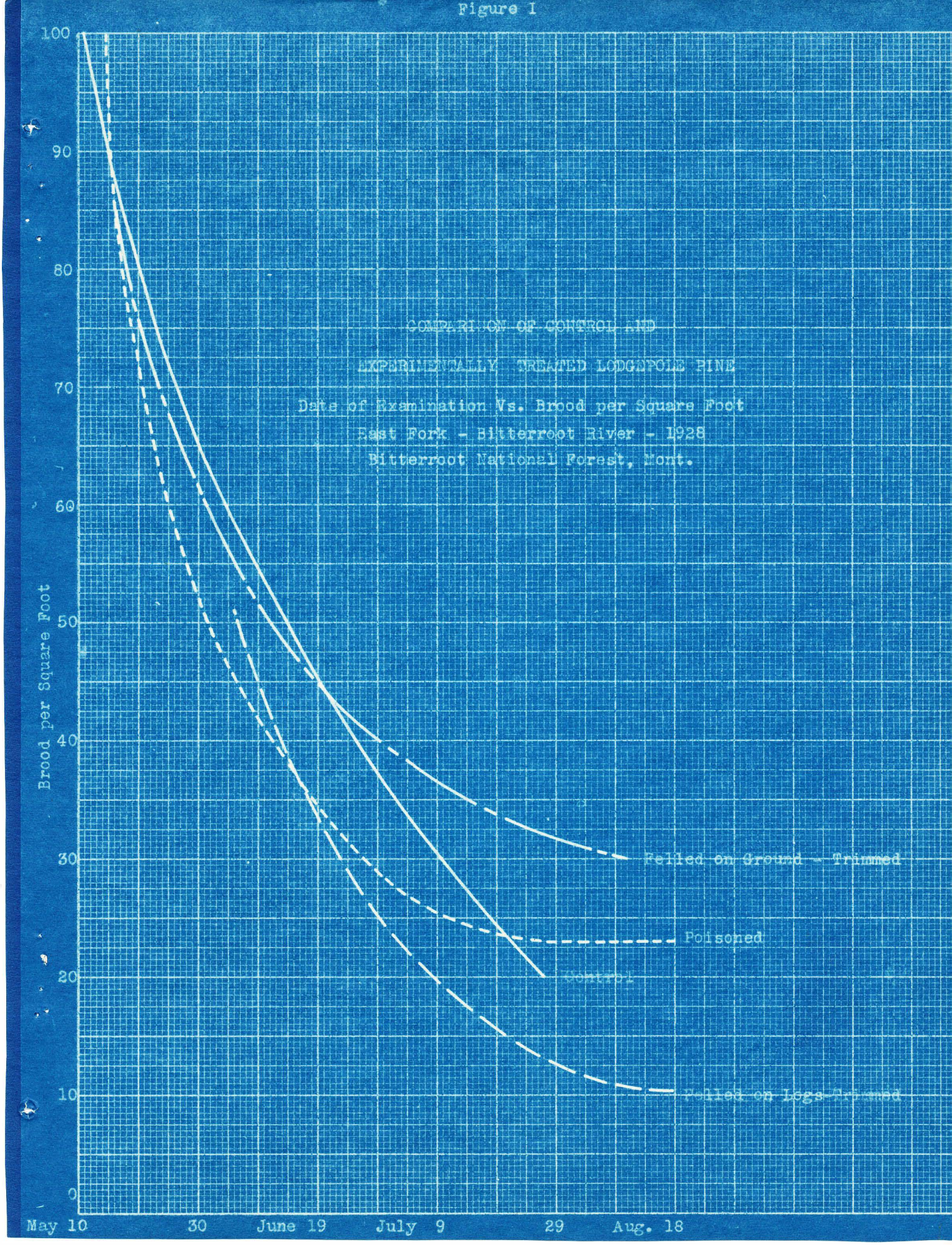
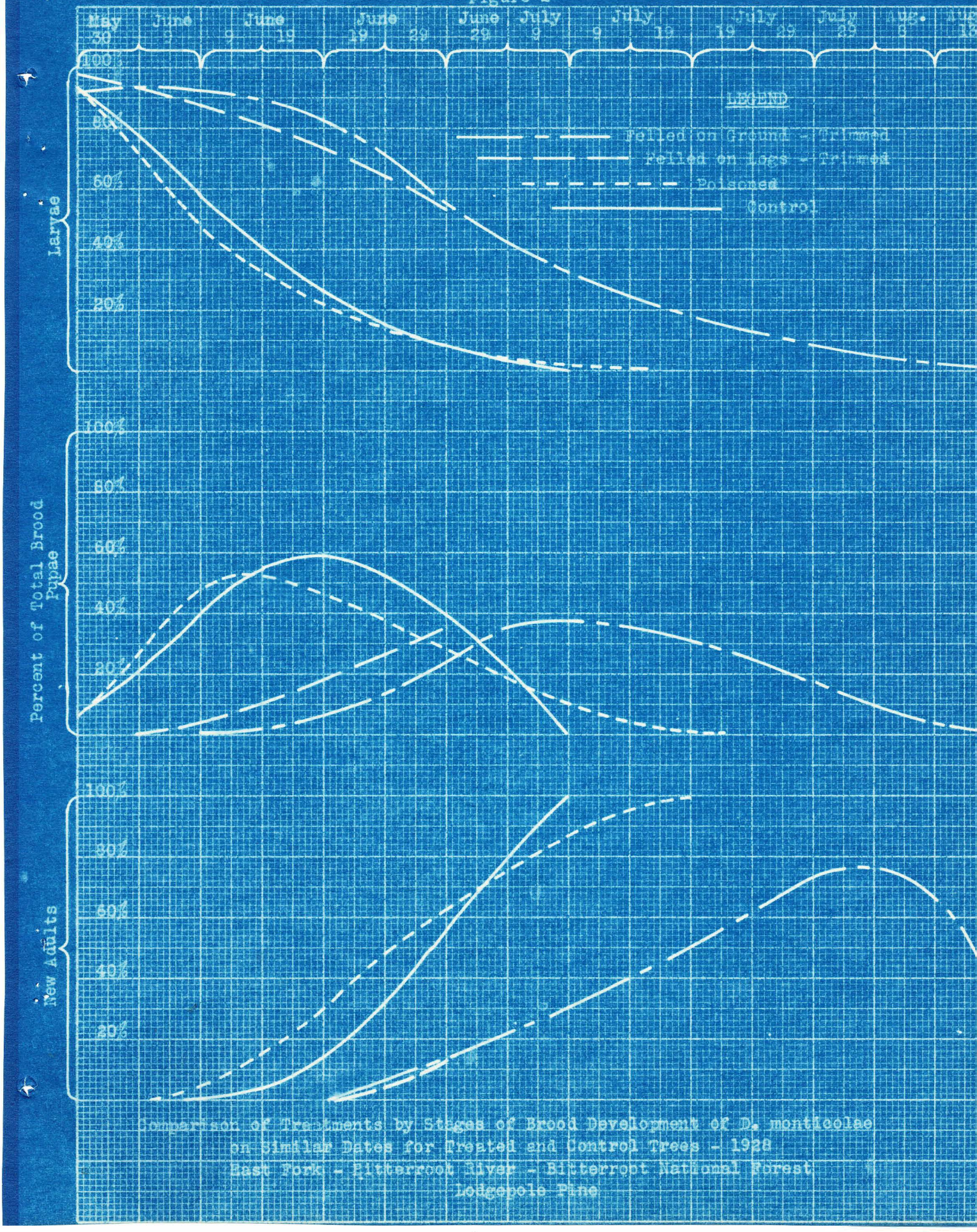

COMPARISON OF CONTROL AND
EXPERIMENTALLY TREATED LODGEPOLE PINE
Date of Examination Vs. Brood per Square Foot
East Fork - Bitterroot River - 1928
Bitterroot National Forest, Mont.
Brood per Square Foot
100
90
80
70
60
50
40
30
20
10
0
May 10
30
June 19
July 9
29
Aug. 18
Felled on Ground - Trimmed
Poisoned
Control
Felled on Legs Undimmed

Figure 2



Comparison of Treatments by Stages of Brood Development of D. monticolae on Similar Dates for Treated and Control Trees - 1928
East Fork - Bitterroot River - Bitterroot National Forest
Lodgepole Pine

F W file.

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF ENTOMOLOGY
WASHINGTON, D. C.

FOREST ENTOMOLOGY
Refer to file
Ent. L-7

Forest Insect Field Station,
Coeur d'Alene, Idaho,
April 1, 1929.

District Forester,
Forest Service Building,
Ogden, Utah.

Dear Sir:

Please find enclosed a copy of Mr. Gibson's report "Investigations Concerning the Mountain Pine Beetle in Lodgepole Pine", which I trust you will find of some interest and information. Your comments and criticisms of this report and the studies which we are undertaking will be appreciated and valued.

Respectfully,

James C. Evenden
Entomologist.

1 enclosure

GPO